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QUININE PELLETS AS AN INFERIOR GOOD AND A GIFFEN GOOD IN RATS

THOMAS HASTJARJO, ALAN SILBERBERG, AND STEVEN R. HURSH[1]

THE AMERICAN UNIVERSITY AND WALTER REED ARMY INSTITUTE OF RESEARCH

In Experiment 1, 4 rats earned their daily food ration by choosing between two levers. One lever delivered two regular and one quinine-adulterated food pellets, and the other delivered two regular and four quinine pellets. A 20-s intertrial interval separated successive choices. Sessions began with 10 forced trials during which only one lever, selected with $p = .5$ and cued by a light above it, could deliver its reinforcer. Forced trials were followed by 30 or 150 trials, depending on the condition, during which choices to either lever could be reinforced. Over this range, absolute choice of the four-quinine, two-regular-pellet lever was inversely related to the number of free-choice trials, establishing this reinforcer as an inferior good. In Condition 1 of Experiment 2, the prior design was altered in two ways: (a) one lever delivered four quinine pellets, and the other lever delivered one standard pellet; and (b) sessions ended after 140 free-choice trials. When the number of free-choice trials was reduced to 100 (Condition 2), all 3 rats increased their preference for quinine pellets, confirming their status as an inferior good. In the next several conditions, the number of quinine pellets provided for selecting its associated lever was varied between three and four. Preference for the quinine-pellet alternative was inversely related to the number of pellets it provided, a result defining it as a Giffen good. These findings are not accommodated readily by extant choice models and complicate the search for a unitary model of choice.

Key words: choice, inferior good, Giffen good, economics, quinine pellets, lever press, rats

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In a study by Elsmore, Fletcher, Conrad, and Sodetz (1980), baboons earned their daily ration of food and heroin by choosing in discrete trials between these alternatives. When the number of trials per day was few, baboons preferred food to heroin, but this preference reversed when there were many trials per day. This finding—that preferences can be altered by a shift in absolute reinforcement levels even though no dimension of relative reinforcement has changed—has been replicated several times (Hursh & Natelson, 1981; Kagel, Dwyer, & Battalio, 1985; Shurtleff, Warren-Boulton, & Silberberg, 1987; Silberberg, Warren-Boulton, & Asano, 1987).

[1] T. Hastjarjo and A. Silberberg are at The American University; S. R. Hursh is at the Walter Reed Army Institute of Research. This research was supported by NSF grants to The American University. Thomas Hastjarjo was supported by the Mucia-Indonesian Second University Development Project. In conducting the research described in this report, the investigators adhered to the *Guide for the Care and Use of Laboratory Animals,* DHEW publication (NIH) 73-23, as prepared by the Institute of Laboratory Animal Resources, National Research Council. The views of the authors do not purport to reflect the position of the Department of the Army or the Department of Defense (para 4-3, AR 360-5). Address correspondence to Thomas Hastjarjo, Department of Psychology, The American University, Washington, D.C. 20016.

The results of the income tests cited above are consistent with a large body of economic data that shows that change in income level (aggregate level of within-session reinforcement) often affects the demand for different goods (reinforcers) unequally (Deaton & Muellbauer, 1980; Prais & Houthakker, 1955). To illustrate, the demand for carpets relative to food is higher among the rich than the poor. This fact suggests that, in choice between these goods, food might be preferred to carpets when income is low but that this preference would diminish and possibly reverse if income rises.

The finding that income level affects choice similarly, whether the alternatives are carpets versus food for humans or heroin versus food for baboons, suggests that there may be value in using economic data to develop new models of nonhuman choice behavior. Indeed, economic data were used in just this way by Elsmore et al. (1980). Income effects long known to economists suggest that psychological models of choice should incorporate income level in predicting preferences. Elsmore et al.'s results proved this suggestion to be true.

For the baboons in the Elsmore et al. (1980) study, and for the vast majority of goods in the

human economy, increases in income lead to unequal and disproportionate but positive changes in consumption. Economists call such goods "normal." However, for an inferior good such as bologna (see Samuelson & Nordhaus, 1985, for other examples), increases in income over some range produce actual decreases in consumption of that good. For example, when people are poor, small increases in income should lead to increased consumption of bologna. But if these consumers become still richer, they will reach a point where they can afford to substitute other, higher quality foods for bologna. This produces an actual decline in bologna consumption, an event defining it as an inferior good.

Silberberg et al. (1987) demonstrated an inferior good in a discrete-trials choice procedure with monkeys. In Experiment 1 of their study, monkeys earned their daily food ration by choosing, in 1-hr sessions, between a small food pellet and a large, bitter-tasting pellet. When income was high, a circumstance arranged by having a short interval between trials, monkeys met their food requirements by consuming small pellets almost exclusively. However, when the number of trials per session was reduced by lengthening the intertrial interval (ITI), their consumption of large, bitter pellets increased while their consumption of small pellets decreased.

In this experiment, the large, bitter pellet was an inferior good because increases in income led to decreases in its consumption. This finding expands the domain of coverage required of any choice model claiming to be comprehensive. As before, a successful model must accommodate the finding, in prior income tests, that preference can change with changes in absolute reinforcement levels even when scheduled relative reinforcement levels are held constant; however, when one good is inferior, this model must also be able to predict that the inferior alternative's reinforcement frequency can drop even when all reinforcement levels are increased equally.

The present experiment attempts to reproduce Silberberg et al.'s (1987) demonstration of an inferior good using rodents as subjects. As in the prior study, choice was on a trials basis between a smaller amount of better tasting food and a larger amount of more bitter-tasting food. Although this study differs in that rats served as subjects, our attention focuses on a procedural difference between this and the prior report: Unlike the prior study, the present study controls income level solely by changing the number of trials per session. As a consequence, any demonstration of an inferior good will occur without arranging any change in the rate of (or delay to) reinforcement. Such an outcome will establish the independence of the inferiority effect from these time-based variables.

EXPERIMENT 1: DEMONSTRATION OF AN INFERIOR GOOD

Method

Subjects. Four experimentally naive male Sprague-Dawley albino rats (Subjects 1, 2, 3, and 4) served as subjects. Water was available continuously in their individual home cages and experimental chambers. They had no access to food between sessions.

Apparatus. A chamber (30 cm by 25 cm by 29 cm) with wire-mesh floor (Coulbourn Instruments model E10-10F) housed in a larger sound-insulated box served as the experimental space. Two 3.5-cm wide levers positioned 19 cm apart and 6.6 cm above the floor were located on the front wall of the chamber. Each lever required a force of 0.25 N to operate. A 28-V stimulus light was located 4 cm above each lever and 25 cm above a food tray centered between the levers and 2 cm above the floor. A water bottle was mounted on one of the Plexiglas side walls.

Procedure. Each session consisted of 10 forced-choice trials followed by a number of free-choice trials that varied across experimental conditions. During each forced-choice trial, one lever was selected as correct, a circumstance signaled by illuminating the light above that lever during that trial. Selection of the signaled lever was random with the constraint that during the 10 forced trials, each lever would be signaled five times. Responding to the unsignaled lever had no scheduled consequences, whereas selection of the signaled lever turned off the houselight and the lever light, turned on the light over the food cup, and initiated the delivery of food pellets (one pellet per second), according to the contingencies in force during the free-choice trials that followed. Following delivery of the last pellet,

Table 1

Order of conditions, number of trials and lever assignments of Experiment 1.

Rat	Condition	Number of trials	Number and type of pellet	
			Right lever	Left lever
1	1	30	2 standard, 1 quinine	2 standard, 4 quinine
	2	150	2 standard, 1 quinine	2 standard, 4 quinine
	3	30	2 standard, 4 quinine	2 standard, 1 quinine
	4	150	2 standard, 1 quinine	2 standard, 4 quinine
2	1	30	2 standard, 1 quinine	2 standard, 4 quinine
	2	150	2 standard, 1 quinine	2 standard, 4 quinine
	3	30	2 standard, 4 quinine	2 standard, 1 quinine
	4	150	2 standard, 4 quinine	2 standard, 1 quinine
3	1	30	2 standard, 1 quinine	2 standard, 4 quinine
	2	150	2 standard, 1 quinine	2 standard, 4 quinine
	3	150	2 standard, 4 quinine	2 standard, 1 quinine
	4	30	2 standard, 1 quinine	2 standard, 4 quinine
4	1	30	2 standard, 1 quinine	2 standard, 4 quinine
	2	150	2 standard, 1 quinine	2 standard, 4 quinine
	3	150	2 standard, 4 quinine	2 standard, 1 quinine
	4	30	2 standard, 4 quinine	2 standard, 1 quinine

the hopper light was extinguished and the houselight was turned on, signaling a 20-s ITI.

In all conditions, one lever delivered two standard 45-mg Bioserv food pellets (Product F0021) and one 45-mg quinine pellet (Product F0233), and the other lever delivered two standard and four quinine pellets. Income level was manipulated by varying the number of free-choice trials per session between 30 and 150. Table 1 presents the income level and lever assignments during each of the four 12-session conditions of this experiment. Daily sessions ended after the free-choice trial limit was reached or after 30 min elapsed without a response.

Results

Figure 1 presents the relative frequency with which the two-standard-pellet and one-quinine-pellet alternative was chosen during each session of the experiment. The solid curve presents performances when the right lever delivered two standard pellets and one quinine pellet and the left lever delivered two standard pellets and four quinine pellets. The dashed curve defines performances when these lever-reinforcer pairings were reversed. Based on the last three sessions of each condition, these data demonstrate that, when income was low (30 trials per session), all rats preferred the larger and (proportionally) more bitter alternative. However, when income was high, this preference reversed, except for Rat 2 in its last condition.

To determine the amount of food consumed in a session, the difference between the number of pellets delivered in a session and the number of pellets present in the floor tray was calculated after every session. Figure 2 presents this result for the last three sessions of each condition. As shown in the figure, more pellets were consumed in high-income than in low-income conditions.

Discussion

The results of this experiment establish the larger, more bitter alternative as an inferior good. This finding, in conjunction with those from other income tests, defines the following effects, which must be accommodated by any model of nonhuman choice behavior purporting to be complete. First, when normal goods serve as reinforcers, this model will predict that equal increases in each schedule's reinforcement level can increase consumption (and, therefore, choice) equally or unequally, depending on the nature of the goods. Second, when one alternative is inferior, this model will predict that increases in income can lead to a selective decrease in choice and consumption of that good. And finally, this model will make these predictions whether or not aggregate income or reinforcement level changed as a function of changes in the rate of, or delay to, reinforcement.

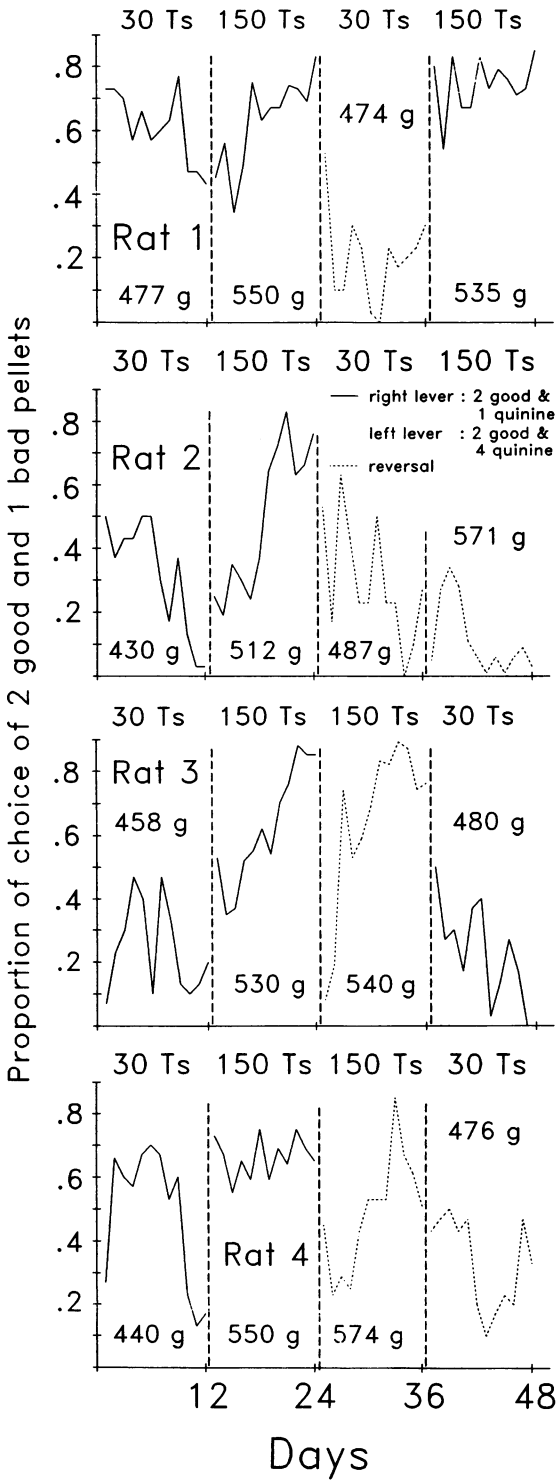

Fig. 1. Relative frequency with which the less bitter alternative was selected as a function of sessions. Body weight before the last session of each condition is presented in each panel. See text for details.

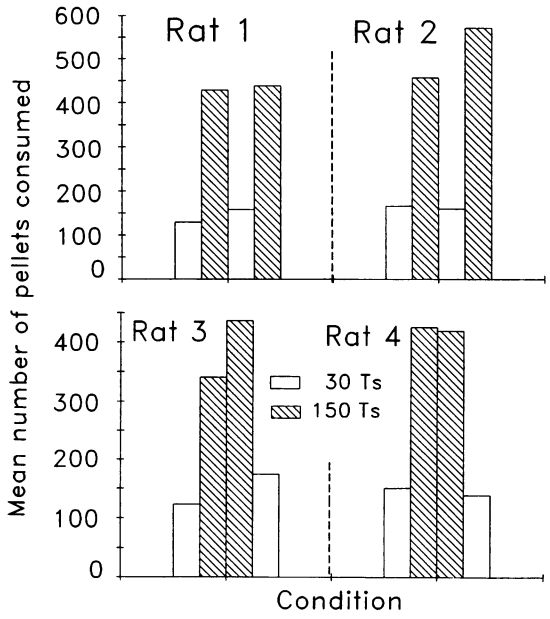

Fig. 2. Each subject's pellet consumption averaged over the last three sessions of each condition.

The finding of an inferior good raises the possibility of complicating still further the required predictive capabilities of an idealized model of choice, because under the appropriate circumstances, an inferior good can become what economists call a Giffen good (see Silberberg et al., 1987). A Giffen good is the only phenomenon that violates the nearly universal prediction that as the price of a good is raised, less of it will be purchased by consumers. Only in the case of a Giffen good do you see a positive relation between its price and consumption.

To illustrate how an inferior good can become a Giffen good, imagine that a hypothetical consumer earns \$8/day and that his large family requires 6 kg of food daily to maintain their body weights. Every day this consumer exhausts his income by buying 5 kg of potatoes at \$1/kg and 1 kg of hamburger at \$3/kg. One day our consumer gets a \$4 raise in salary. With \$12 in hand, he now purchases 3 kg of hamburger (\$9) and only 3 kg of potatoes (\$3). Because he has purchased fewer potatoes despite the increase in income, potato is an inferior good.

To transform this inferior good into a Giffen good, imagine that the grocer now raises the price of potatoes to \$2/kg. Because our consumer needs 6 kg of food to feed his family, he can no longer afford to purchase any ham-

burger. Instead, he must spend his income exclusively on potatoes. Paradoxically, in response to an increase in the price of potatoes, our consumer is forced to buy more potatoes.

In their second experiment, Silberberg et al. (1987) tested whether the bitter pellet used in their first study could be a Giffen good as well as an inferior good. In Phase 1 of their test, 2 monkeys earned their daily food ration during 1-hr sessions by choosing, every 15 s, between a key that delivered a large bitter pellet with $p = .5$ and a key that delivered a small standard pellet with $p = .35$ for 1 subject and .25 for the other. Once preferences stabilized, they raised the price (responses or time per reinforcer) of the bitter food by reducing to .4 the probability that its key would deliver this pellet. The price of the standard pellet was left unchanged. In response to the increase in price for the bitter pellet, both monkeys increased their choices of it so that they consumed more bitter pellets in Phase 2 than in Phase 1. Because they "demanded" more of the bitter pellet once its price was raised, it was a Giffen good.

In the next experiment, we attempted to reproduce this Giffen-good effect. Unlike in Experiment 1, the quinine and standard pellets were no longer mixed. Instead, selection of one lever delivered only standard pellets and selection of the other lever delivered only quinine pellets. The design differs from that of Silberberg et al. (1987) in that the price of the bitter alternative was manipulated, not by its likelihood of delivery, but by the number of pellets delivered. For this commodity to be a Giffen good over this range, preference for this lever should increase as the number of pellets it delivers decreases.

EXPERIMENT 2: DEMONSTRATION OF A GIFFEN GOOD

In this experiment, the two alternatives no longer consisted of different mixtures of quinine and standard pellets. Instead, the intended normal good was a single standard pellet and the intended inferior good was four quinine pellets. Because the to-be-inferior good was changed from Experiment 1, the first goal of this study was to demonstrate the inferiority of the four-quinine-pellet alternative. Toward this end, in the first two phases of this study rats chose on a trials basis between four quinine versus one standard pellet when income was high (140 trials, Phase 1) and when income was low (100 trials, Phase 2). If quinine-pellet selection increases as a consequence of this income manipulation, we will have demonstrated that the quinine outcome is an inferior good.

Table 2
Order of conditions and lever assignments of Experiment 2.

Rat	Condition	Right lever	Left lever
1	1	1 standard	4 quinine
	2	1 standard	4 quinine
	3	1 standard	3 quinine
	4	1 standard	4 quinine
	5	4 quinine	1 standard
	6	3 quinine	1 standard
	7	4 quinine	1 standard
	8	3 quinine	1 standard
	9	4 quinine	1 standard
3	1	1 standard	4 quinine
	2	1 standard	4 quinine
	3	1 standard	3 quinine
	4	1 standard	4 quinine
	5	4 quinine	1 standard
	6	3 quinine	1 standard
	7	4 quinine	1 standard
	8	3 quinine	1 standard
4	1	1 standard	4 quinine
	2	1 standard	4 quinine

Given that the quinine-pellet alternative proved to be inferior, we manipulated the number of these pellets delivered in choice. For these pellets to be labeled a Giffen good, there must be an inverse relation between preference for quinine pellets and the number of these pellets delivered. In particular, when the inferior good is composed of four pellets, it should be preferred less than when it is composed of three pellets.

METHOD

Subjects. Subjects 1, 3, and 4 from Experiment 1 served. Rat 2 was excluded from this test because, in the last phase of the prior study, it failed to demonstrate the inferiority effect.

Apparatus. The apparatus was the same as in the prior experiment.

Procedure. Table 2 identifies, for every condition and subject, whether a particular lever delivered a standard pellet or quinine pellets and the number of quinine pellets delivered. Except for the first condition, which was com-

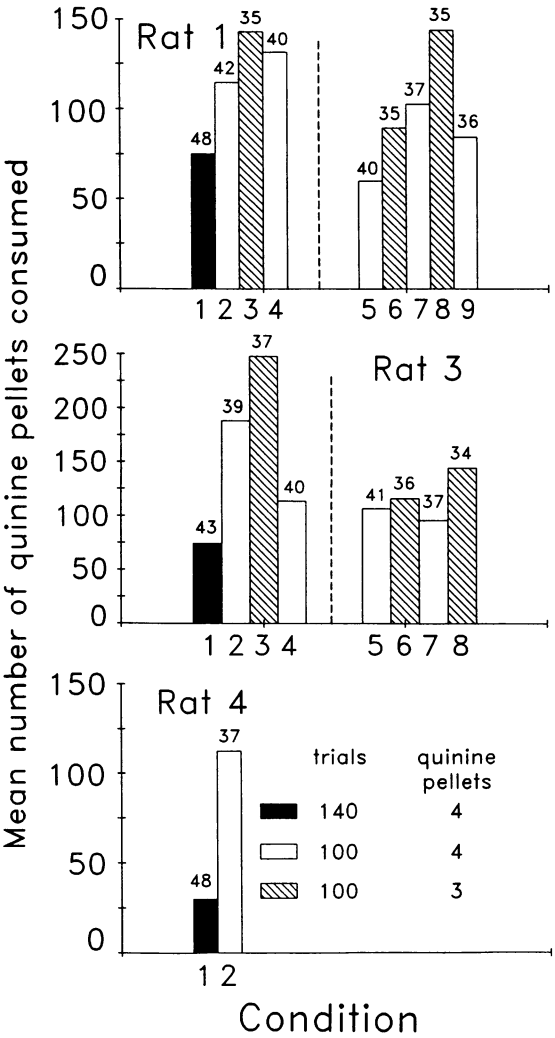

Fig. 3. Mean number of quinine pellets consumed during the last four sessions of each condition. Body weight × 10 g (e.g., 48 = 480 g) before the last session of each condition is presented atop individual bars of each histogram. See text for details.

posed of 140 free-choice trials, daily sessions ended after 100 free-choice trials. Each condition ended after 20 sessions. All other features of the procedure were the same as in the previous experiment.

Results and Discussion

Figure 3 presents the number of quinine pellets consumed averaged over the last 4 days of each condition for all subjects. The solid bar indicates consumption during the high-income (140 trial) condition. The clear and hatched bars define consumption when the quinine lever delivered four and three pellets, respectively. Conditions to the left of the dashed vertical line present consumption data prior to reversing lever–reinforcer assignments and those to the right present data after these assignments were reversed.

For the four-quinine-pellet alternative to be inferior, the consumption of quinine pellets should increase when the number of trials was reduced from 140 to 100. Comparison between the solid-bar and the clear-bar data adjacent to it establishes that consumption of quinine pellets was higher when trials were fewer. Hence, quinine pellets were an inferior good.

Having established the inferiority of quinine pellets, we can now evaluate whether they had properties of a Giffen good. For quinine pellets to be Giffen, increasing their price, expressed as a reduction in the number of pellets per lever press, should lead to an increase in their selection. Except for a comparison between Conditions 6 and 7 for Rat 1, this requirement was fulfilled. Indeed, if comparisons are restricted to successive phases—a step that seems sensible given that price was alternately raised and reduced as each condition changed—then 10 of 11 comparisons are compatible with labeling quinine pellets a Giffen good.

No data relevant to a Giffen-good test are presented for Rat 4 because this subject was dropped from the experiment when its body weight fell below 70% early in Condition 3.

The data in Figure 3 present performance in terms of consumption, because economists use consumption to determine whether a good is inferior or Giffen. The data in Figure 4 are presented in a manner more familiar to the behavior analyst, where choice, and not consumption, is used to define performance. In this figure we see two outcomes: First, reducing the number of trials between the first and second conditions led to an increase in choice of the quinine alternative; second, for all comparisons within prereversal conditions (Conditions 1 through 4) and reversal conditions (Conditions 5 through 9), preference for the quinine pellets decreased every time the number of pellets composing this outcome increased and increased every time their number decreased.

In the present report we argue that choice between food sources is governed to a large degree by the total food intake these sources

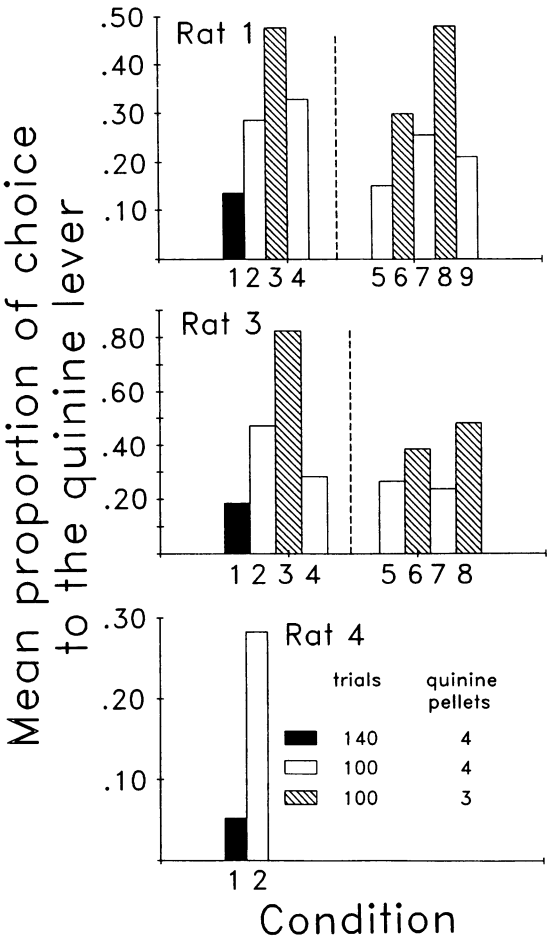

Fig. 4. Relative frequency with which the bitter alternative was selected during the last four sessions of each condition.

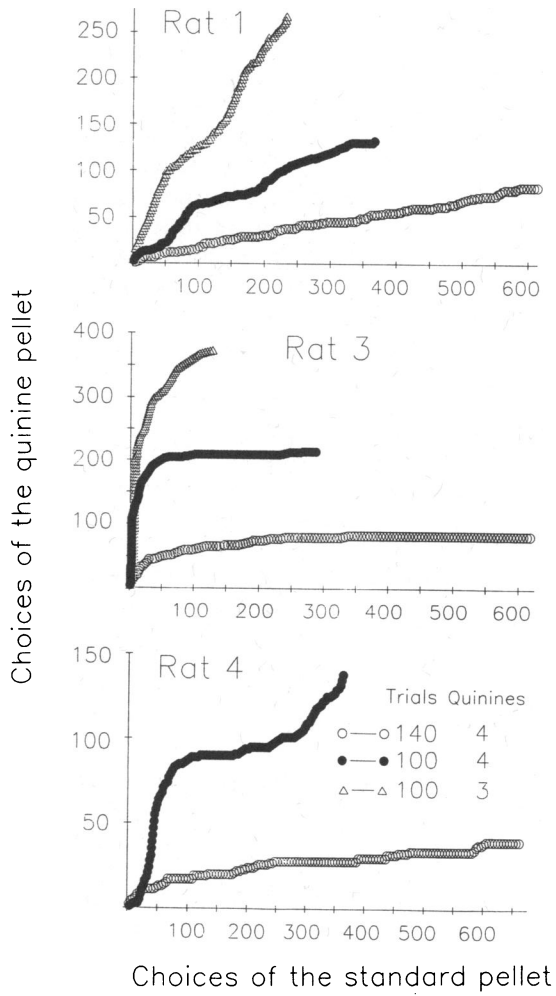

Fig. 5. Cumulative choices of quinine versus standard pellets during the last five sessions of each of the first three conditions of Experiment 2. Rat 4 was exposed to only two conditions.

can provide and not by more contemporaneous variables such as the ongoing relative rate, amount, or quality of reinforcement. If rats select different choice ratios based on anticipated daily income from a session, it should be reflected not only in choice totals at the end of a session but also in choice ratios *throughout* the session. Such a demonstration is important in obviating another explanation for this study's results—that choice ratios vary solely as a function of food consumed within a session. According to such an account, choice shifts toward greater consumption of the standard food pellet as the session progresses. Different choice ratios occur in different conditions of the present report not because different choice rules were used in each condition but because of changes in choice ratio that accompany diminishing hunger.

Figure 5 addresses this issue. It defines the consumption path of choice summed over the last five sessions for each rat during each of the first three conditions of Experiment 2. These functions outline cumulatively how preference changed as a function of the number of trials that had passed in a session. Except for the first 25 trials (125 trials when summed over five sessions) for the 100-trial versus 140-trial four-quinine-pellet conditions for Rat 3, there was virtually no overlap in the consumption paths followed by a rat among its different conditions. In other words, choice ra-

tios differed among conditions not only in terms of final choice ratios (terminus of each consumption curve) but also throughout most of each session. Generally speaking, rats consistently followed different choice rules that could be more readily predicted by considering the total food income that would be offered in a session than by considering other variables, such as relative rates of reinforcement.

GENERAL DISCUSSION

Silberberg et al. (1987) created a discrete-trials choice procedure in which a bitter food met the criteria for being an inferior good and a Giffen good. The present study replicates these outcomes and does so in a way suggesting that these effects are robust procedurally: We now know that inferior goods and Giffen goods exist for rats as well as monkeys and for income manipulations based on varying trial number as well as varying ITI duration. Moreover, we have also shown that a good can be inferior not only when choice is between goods that differ qualitatively in taste (bitter vs. standard food in Experiment 2) but also when they only differ in degree (more vs. less bitter food in Experiment 1). The results are reminiscent of those of Fantino and Preston (1988) who, using an operant analog of foraging, found that as the less preferred of two outcomes became more accessible it became either more or less acceptable, depending upon the way accessibility was manipulated.

Courses in microeconomics have long pointed to the Giffen good as the one logical exception to the law of demand. Yet its existence in theory seems more secure than its existence in fact. Indeed, economists have no uncontested illustrations of a Giffen good in the human economy (Dwyer & Lindsay, 1984; Kohli, 1986; Stigler, 1947, 1948). For this reason, the demonstration in this report and in Silberberg et al. (1987) that a bitter food can be a Giffen good may prove of interest to the microeconomist.

These results should also interest the behavior analyst, because in conjunction with prior work on concurrent schedules (e.g., de Villiers, 1977), they establish a range of choice outcomes so broad as to complicate severely a popular behavior-analytic goal: creating a unitary model of choice (e.g., Herrnstein, 1970). To illustrate the problem as it relates to the Giffen-good effect, a comprehensive model of choice must now be able to predict that increasing one of two reinforcer amounts can lead to increased preference for the changed alternative (e.g., Catania, 1963) or decreased preference for that alternative (present report). With regard to the demonstration of an inferior good, this model must now predict changes in preference not only when, say, rates of reinforcement are changed (e.g., Herrnstein, 1970) but also when the session-wide income level (i.e., trial number) is altered with all temporal parameters (except session length) fixed.

A behavior analyst might defend traditional choice accounts in several ways. One argument could be that the difficulties introduced in the data of the present report hold only for "composite" foods such as a quinine-adulterated pellet and not for the broad range of "unitary" foods that normally serve as reinforcers. To us, such an argument does not seem defensible. There is no food whose sole characteristic is the pure calorie. Indeed, all goods are composites of many characteristics. Any procedure that forces a restructuring of the importance of those characteristics to a rat could potentially produce a Giffen good.

A second defense might question the relevance of a Giffen good based on the artificiality of the economy in which it appears. Here a critic might be on surer ground, for the circumstances necessary to produce a Giffen good are so unusual that there are no uncontested documentations of their occurrence in the human economy. Nevertheless, the artificiality of this economy does not justify claiming as comprehensive models of choice that ignore its effects.

One dominant theme of behavior analysis over the last two decades has been a search for a unitary model of choice (e.g., Herrnstein, 1970). Although we do not contend that such a goal cannot be realized, the data from this report question the adequacy of prior models of nonhuman choice behavior and call for changes in how we attempt to model choice. In our view, we need to move away from evaluating choice between identical reinforcers delivered by schedules that differ, say, only in the rates of reinforcement they provide. Instead, we should move to more natural situations in which choice is between goods that

actually differ in kind and in which each choice delivers the good selected. If the experience of the economist is any guide, the decision rules that are developed from this new work will be more complex and more restricted in their domains of coverage. Although these outcomes are, in some respects, disappointing, we can benefit from the likelihood that these less comprehensive models will be more durable than the comprehensive theories of choice developed by behavior analysts to date.

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